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Retraction

Retracted: Elucidation of Nature of Gene Action and Estimation of Combining Ability Effects for Fruit Yield Improvement and Yield Attributing Traits in Brinjal Landraces

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] N. Rajan, S. Debnath, A. K. Dutta et al., "Elucidation of Nature of Gene Action and Estimation of Combining Ability Effects for Fruit Yield Improvement and Yield Attributing Traits in Brinjal Landraces," *Journal of Food Quality*, vol. 2022, Article ID 8471202, 12 pages, 2022.

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Research Article

Elucidation of Nature of Gene Action and Estimation of Combining Ability Effects for Fruit Yield Improvement and Yield Attributing Traits in Brinjal Landraces

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Genetic progress in quantitative traits can be improved by understanding how genes interact and estimating the consequences of combining abilities. As a result, a randomized block design with three replications was used to conduct forty crossings using a line X tester mating design with ten lines and four testers. All of the qualities were shown to be highly variable based on the ANOVA (analysis of variance) results among lines, testers, and hybrids. An estimated predictability ratio showed a high prevalence of nonadditive gene action, which was further confirmed by the lower narrow-sense heritability values for all traits. Most of the characters had high general combining ability and specific combining ability estimates, showing the relevance of both additive and nonadditive gene effects, respectively. For all of these features, however, the specific combining ability variations were greater than the general combining ability variances. Since heterosis breeding can lead to better hybrids, it may be a good idea to do so. For most yield-related parameters, such as fruit diameter, fruit per plant, marketable fruit per plant, yield per plant, marketable yield per plant, and total yield, RKML-26 and RKML-34 were the best general combiners among all lines. So, these lines might be employed as parents in hybridization programme in future to get suitable recombinants for higher fruit yield. However, the best cross combinations for commercial hybrid exploitation were RKML-26 X Pusa purple cluster (PPC) and RKML-2 X Swarna Shyamli. These crosses exhibiting higher per se performance and desirable specific combining ability effects together with either both or at least one parent as a competent combiner would be rewarding for heterosis breeding. Combining traditional breeding methods with biotechnological approaches, according to a new study, is critical for the transfer of favorable genes (traits) into farmed plants.

1. Introduction

Brinjal (*Solanum melongena L.*) is a prominent Indian solanaceous vegetable crop. The nutrient-dense fruits of this vegetable contain a wide range of phytochemicals, minerals, vitamins, fiber, and antioxidants [1, 2]. Brinjal is a year-round vegetable throughout tropical and subtropical regions across the globe. It 'is a popular vegetable that may be utilized in a variety of ways in agroclimatic zones and may be grown at any period of year [3, 4]. However, the ITPGFRA (International Treaty on Plant Genetic Resources for Food and Agriculture) recognizes brinjal as an important crop for addressing global food insecurity [5]. Brinjal is a popular vegetable in Asia and is considered to be one of the more successful. Brinjal occupies 758 thousand hectares in India and yields 13.15 million tons [6, 7]. Brinjal is a climate-adaptable crop that may be cultivated in a range of conditions. It may be cultivated at any time of year. Brinjal accounts for 8.14% of total vegetable acreage and 9% of total vegetable output in India. Because of its medicinal and nutritional characteristics, it is being hailed as a future crop. India has a wide range of genetic resources for eggplant, including a wide range of plant types, fruit colors, shapes, sizes, yields, and other quality attributes [8, 9]. Previously, mass screening and pure line selection among landraces were employed to develop improved eggplant cultivars. It is evident that selecting parents on the basis of performance does not just produce the desired results [3, 10]. Diverse breeding approaches are needed to efficiently transfer beneficial genes into economically superior high-yielding cultivars in order to make efficient use of these genetic resources [11]. Breeders can choose suitable genotypes as parents during hybridization for enhanced cross combos by investigating general combining ability (GCA) and specialized combining ability (SCA). As a consequence, the new research was carried out to investigate brinjal's ability to integrate agricultural traits [12, 13]. Appropriate parent selection based on their potential to combine is a must for every breeding effort. Combining ability analysis also tends to suggest the nature of gene action implicated in the inheritance of specific traits. Understanding gene action enables the selection of the most suitable breeding strategy for genetic improvement of a variety of quantitative traits. Gene action is quantified in terms of genetic variation components or by combining ability variance and effects. The genetic variation in homozygous genotypes is entirely additive and additive-epistemic, but in segregating populations, both additive and nonadditive genes are present [14].

In India, 32.2% of indigenous brinjal cultivars are produced owing to customer preferences for their quality features and their tolerance to hostile environments. It is a significant source of genetic variation for contemporary plant breeding, which may be used to increase tolerance to abiotic or biotic stresses, yield performance, and quality attributes in limiting environments [15, 16]. It is one of the most important vegetables in Jharkhand, and according to the report of the Horticulture State Division (2018), it is cultivated year-round on around in 80.09 thousand hectares, yielding 252.60 thousand tonnes [17]. The Chota Nagpur area of Jharkhand's Eastern Plateau boasts a wide variety of oblong and round fruits that are preferred by locals [18]. Different landraces of brinjal are mostly grown by farmers in the state according to local preference. As a result, the state's brinjal production is lower than in other places where hybrid cultivars are more widely used. Consumers' preferences will not be compromised in the process of improving brinjal's quality and production. In Jharkhand, brinjal has a wide variety of landraces that may be used to develop a superior genotype that can then be used for commercialization [19]. As a result, it is critical to understand the potential of important brinjal lines extant in the state for use in the development of high-yielding cultivars before they go extinct. Indigenous brinjal landraces provide a greater opportunity to develop a superior variety from the existing local types, particularly in Jharkhand's commercial conditions. However, the proposed method will aid in increasing crop productivity. For heterosis breeding, these crossings with greater per se performance and favorable specific combining ability effects, as well as either both or at least one parent as a skilled combiner, would be profitable.

In order to increase the landraces' producing potential, it is necessary to understand the sort of gene action that determines the inheritance of yield and its contributing features. Combining ability variances are used as a measure of gene action. Identification of attractive parents in a breeding programme or identification of better cross combinations for cultivar development is made easier with the capacity to combine [20]. Diallel, partial diallel, and a line x tester are various ways of combining the ability to estimate demands. Specific combining ability values for each cross and general combining ability for lines and testers are provided by the simplest mating design, the line x tester. In brinjal, identifying suitable parents and evaluating the hybrid's appropriateness to a certain location are critical [21]. Plants are continually subjected to unfavorable growth conditions throughout their product lifecycle, so their ability to withstand these stresses while still reproducing is crucial for sessile species like plants. Their responses to abiotic stresses are diverse and complex [22, 23]. Crop breeding programmes that include at least one parent with a high general combining ability value and a large specific combining ability impact, as well as a hybrid with high per se performance are more dependable than those that do not include at least one parent with a high general combining ability value when making parent selections [24]. Due to the predominance of additive gene action in self-pollinated species, mass selection and progeny selection should be used. If nonadditive gene action prevails, the breeding focus should be to generate hybrids for commercial purposes. We performed a scientific experiment to determine the kind of gene action driving yield and yield-contributing traits, as well as to identify parent and cross lineages that may be used in future breeding programmes. Several academics have done similar studies on local landraces in the past [25–27].

2. Materials and Methods

RKMVERI's Ranchi Research Farm was used for this research during 2018-19 and 2019-20. It was decided to use 14 distinct genotypes for the study because of the variety of qualities they had. Four genotypes as testers and ten as lines collected from various regions of Jharkhand were employed in the study. Our staff selected the lines for this project from a pool of core collection. The DUS (distinctness, uniformity, and stability) criteria of the Protection of Plant Varieties and Farmers' Rights Authority, Ministry of Agriculture and Farmers Welfare, Government of India, were used to assess and analyze these indigenous lines gathered from various agroclimatic zones of Jharkhand, India. This was reported in a preliminary investigation that was later published [28].

These lines will be forwarded for registration when they have been catalogued, and other appropriate investigations have been completed. Only one of the 10 genotypes produced purple-tinged cylindrical fruit, while the other nine produced green obovate fruit. Fruit from all other genotypes was covered in spots, except for the purple one. Genotypes RKML-1, 2, 3, 4, 5, 6, 7, 11, 26, and 34 were identified. The male parents utilized were Pusa purple cluster, Pusa purple long, Swarna Pratibha, and Swarna Shyamli. A line *X* tester mating design was used to produce forty crossovers from all the genotypes. Following that, three replications of each cross and its parents were grown in a randomized block design for assessment. Plants for each submission were spaced 75×50 cm apart on plots of 9 square meters. Standard cultural practices were followed in accordance with BAU (Birsa Agricultural University) standards. Five randomly selected plants from each genotype were studied over replications to collect data on various quantitative characters, such as the number of primary branches, leaf length, leaf width, petiole length, fruit length, fruit diameter, number of fruits per plant, number of marketable fruits per plant, single fruit weight, seed per fruit, yield per plant, marketable yield per plant, and total yield per hectare. There was a lot of information gathered from the whole plot on characteristics such as flower initiation, days to 50% blooming (fruit initiation), stem rot incidence percentage, and plant survival. According to Kempthorne's technique [29], these data were utilized to estimate general combining ability, specific combining ability, and gene action [30]. Data were analyzed in R using package Agricola Version: 1.3–5.

3. Results and Discussion

The analysis of variance (ANOVA) for line *x* tester for twenty-one characters of brinjal is given in Table 1, which indicate that the lines, testers, and their interactions showed significant differences for all the characters. The proportion of the mean sum of squares due to lines was more than that due to testers for the traits viz., days to the first flower, days to 50% flowering, fruit initiation, leaf length, leaf width, number of primary branches, petiole length, yield per plant, marketable yield per plant, total yield, total phenol, and ascorbic acid. However, the proportion of the tester's contribution was more than that due to lines for remaining characters, i.e., fruit length, fruit diameter, fruit per plant, marketable fruit per plant, fruit weight, seed per fruit, sclerotia stem rot incidence, and dry matter. Therefore, ANOVA suggested the presence of wide variability for the respective traits among the lines and testers.

The estimates of combining ability variances are a measure of gene action. General combining ability (GCA) variance measures additive gene action, and specific combining ability (SCA) variance measures nonadditive gene action. If general combining ability variances are more than specific combining ability variances, early generation testing of genotypes becomes more fruitful due to chance of fixing superior genes would be greater; whereas, in the vice-versa situation, the selection is advised to be practiced in later generations [29, 31, 32]. The magnitude of general combining ability and specific combining ability variances for different quantitative characters in brinjal is given in Table 2. The result revealed that the magnitude of specific combining ability variances was greater than general combining ability variances for all the characters, indicating a preponderance of nonadditive gene action, which is always favorable for heterocyst breeding for the improvement of these traits. Similar outcomes were accounted by several previous studies [33–36]. The study also revealed that the degree of dominance was higher than unity, suggesting a more significant proportion of dominant genes in the expression of these traits. The ratio of additive to nonadditive variance is referred to as the predictability ratio. It indicates the relative impact of estimations of general and specific combining abilities in anticipating progeny performance. Reduced predictability ratios (less than 0.5) for all 20 quantitative characters suggest a strong contribution for nonadditive gene action caused by dominance, epistatic, and numerous other interaction effects. The predominance of nonadditive genetic variance suggested that the population comprised of heterozygotes. As such, this sort of genetic variation is unfixable, making hybridization an appropriate method for crop improvement. The estimate of narrow-sense heritability was low for all the traits and ranged from 1.98 to 6.17%, again in agreement with the predominance of nonadditive gene action. Higher values of particular combining ability relative to general combining ability were shown to be associated with a preponderance of nonadditive gene action as described by many earlier workers [37, 38]. Relative involvement to the total variance by lines, testers, and interactions is also shown in Figure 1, and it was revealed that the lines had contributed more than testers in respect of all traits.

The estimates of general combining ability effects are given in Table 3. No lines were established as the best general combiner for all the traits among ten lines. Many previous studies showed similar trends [39, 40]. RKML-26 and RKM L-34 had shown a favorable general combining ability effect for fifteen characters, viz., leaf length, days to first flowering, 50% flowering, fruit initiation, fruit diameter, fruit per plant, marketable fruit per plant, fruit weight, petiole length, yield per plant, marketable yield per plant, seed per fruit, total yield, sclerotia stem rot incidence%, and dry matter%. So, these genotypes were identified as the best general combiners in this study. Swarna Shyamli was the best general combiner in round green fruit type among four testers with a significant favorable general combining ability effect for traits like days to first flower, 50% flowering, fruit initiation, fruit diameter, fruit length, fruit weight, marketable yield per plant, sclerotia stem rot incidence%, and dry matter%. These parental lines will be further exploited to develop promising cultivars like disease-resistant, high-yielding, early varieties. Pusa purple cluster was the second-best general combiner in the purple cylindrical fruit segment type with a positive significant general combining ability effect for eight yield and yield-contributing traits and phenol content. This result kept strong evidence of a desirable gene flow from parents to offspring with high intensity and provided information about predominantly additive genes' concentration [34].

Table 1: ANOVA for line *x* tester analysis for different characters of brinjal.

Source of variation	DF	DFI	DF50	FI	LL	LW	NPB	Pl	FL	FD	FPP	MFPP	FW	YPP	MYPP	SPF	TY	SSR	DM	TP	AA
Replications	2	27.72	60.08	36.52	2.21	2.46	2.6	1.05	2.46	4.4	36.14	64.9	388.75	223022.97	383210.59	21576.71	255.83	470.99	0.92	1.75	1.18
Treatments	53	202.36**	189.38**	151.11**	8.84**	5.1**	3.38**	2.14**	28.9**	68.13**	215.01**	169.63**	5223.89**	1056513.49**	884802.46**	1234032.06**	599.26**	261.8**	16.4**1	688.62**	10.9**
Parents	13	222.56**	228.93**	194**	2.16**	8.08**	4.88**	5.54**	45.43**	73.11**	173.22**	143.48**	8767.83**	914323.6**	906240.98**	917774.15**	282.48**	242.86**	28.52**	984.47**	7.15**
Hybrids	39	198.33**	177.49**	140.6**	9.34**	3.3**	2.52**	0.95**	21.2**	67.55**	220.78**	171.59**	3434.81**	1123331.22**	895833.84**	1344419.69**	625.12**	272.88**	12.54**	607.65**	7.74**
Parents vs. hybrids	1	96.84**	138.92**	3.68**	76.1**	36.45**	17.45**	4.16**	114.22**	25.96**	533.42**	433.23**	28926.65**	299090.96**	175877.84**	1040267.51**	3708.74**	75.66**	10.12**	0.23**	182.66**
Lines	9	640.41**	616.5**	382.83**	22.8**	7.84**	5.09**	2.76**	41.92**	61.42**	390.58**	365.7**	2876.99**	2871163.26**	2349583.5**	2905346.78**	1644.21**	353.33**	22.31**	1544.37**	23.1**
Testers	3	152.32**	104.7**	178.32**	8.61**	4.2**	2.56**	1.72**	79.4**	388.33**	1305.49**	822.51**	29902.03**	1073701.11**	918090.19**	4785351.27**	579.97**	952.5**	56.24**	1201.58**	17.67**
Lines X testers	27	56.09**	39.24**	55.67**	4.93**	1.69**	1.65**	0.26**	7.83**	33.96**	43.65**	34.57**	679.95**	546234.99**	408777.69**	441784.93**	290.44**	170.56**	4.42**	229.42**	1.52**
Error	106	13.7	14.36	18.6	0.1	1.37	0.51	0.3	2.88	3.58	15.72	13.8	146.99	64976.79	58320.9	36717.72	80.65	51.02	1.03	0.19	0.13

*, **Significant at 5% and 1% levels, respectively. DF, degree of freedom; DFI, days to flower initiation, DF50 days to 50% flowering; FI, fruit initiation; LL, leaf length (cm); LW, leaf width (cm); NPB, number of primary branches; Pl, petiole length (cm); FL, fruit length (cm); FD, fruit diameter (cm); FPP, number of fruit per plant; MFPP, number of marketable fruit per plant; FW, fruit weight (g); YPP, yield per plant (g); MYPP, marketable yield per plant (g); SPF, number of seed per fruit; TY, total yield (ton/ha); SSR, sclerotia stem rot incidence%; DM, dry matter%; TP, total phenol (mg/100 g); AA, ascorbic acid (mg/100 g).

Table 2: Estimates of GCA and SCA variances and genetic parameters in brinjal crosses.

Cross	DF	DF50	FI	LL	LW	NPB	PL	FL	FD	FPP	MFPP	FW	YPP	MYPP	SPF	TY	SSR	DM	TP	AA
Cov H.S. (lines)	48.69	48.1	27.26	1.49	0.51	0.29	0.21	2.84	2.29	28.91	27.59	183.09	193744.01	161733.8	205296.8	112.81	15.23	1.49	109.58	1.8
Cov H.S. (testers)	3.21	2.18	4.09	0.12	0.08	0.03	0.05	2.38	11.81	42.06	26.26	974.07	17582.2	16977.08	144785.6	9.65	26.06	1.72	32.4	0.54
σ^2GCA	2.33	2.27	1.39	0.07	0.03	0.01	0.01	0.22	0.55	2.91	2.25	45.22	9472.54	7994.61	14815.97	5.49	1.68	0.13	6.21	0.1
σ^2 A with $F=1$	4.67	4.54	2.79	0.14	0.05	0.03	0.02	0.44	1.1	5.81	4.5	90.44	18945.08	15989.22	29631.95	10.99	3.36	0.27	12.42	0.2
σ^2SCA (i.e., σ^2 D)	15.26	9.61	13.67	1.61	0.27	0.4	0.03	1.77	9.98	7.95	5.74	175.72	155324.01	115734.5	131080.6	70.54	40.48	1.09	76.41	0.46
Predictability ratio	0.23	0.32	0.17	0.08	0.18	0.05	0.4	0.2	0.18	0.42	0.44	0.34	0.11	0.12	0.18	0.13	0.08	0.19	0.14	0.3
Degree of dominance	1.81	1.45	3.14	3.39	2.32	3.65	1.22	2.84	4.25	1.65	1.13	1.39	4.05	2.69	2.97	3.58	3.47	2.01	2.48	1.52
Type of dominance	OD	OD	OD	OD	OD	OD	OD	OD	OD	OD	OD	OD	OD	OD	OD	OD	OD	OD	OD	OD
Narrow- sense heritability (%)	5.68	6.17	4.24	3.99	2.83	2.31	4.34	3.36	2.4	3.59	3.87	3.07	4	4.19	3.97	3.84	1.98	3.36	4.65	5.35

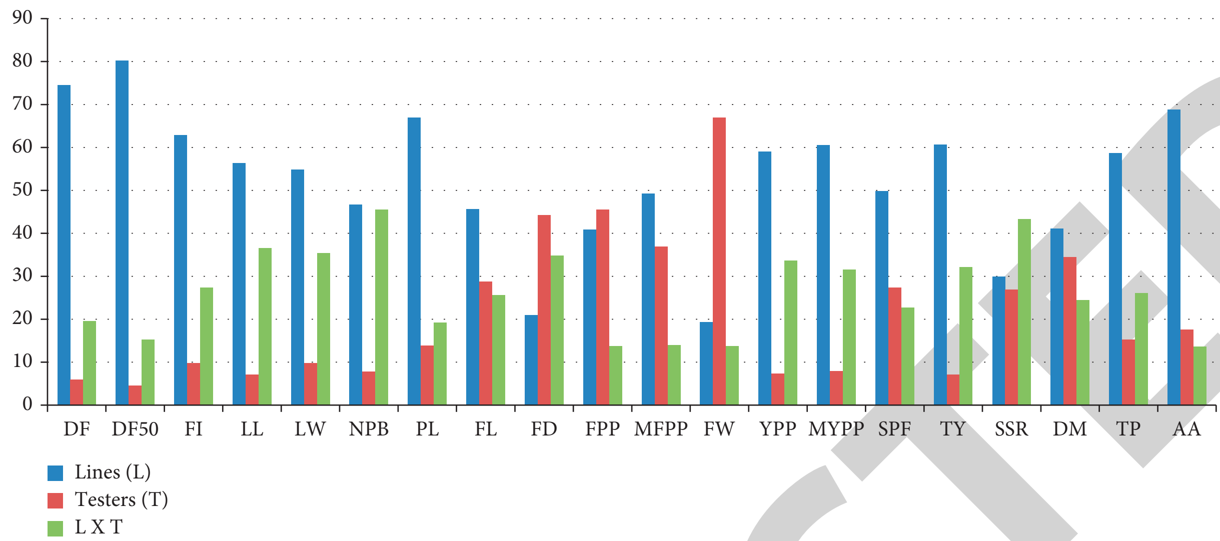

Figure 1: Relative contribution to the total variance by lines, testers, and line X tester.

Therefore, the parental lines, i.e., RKML-26 and RKML-34 (used as a female parent) and Pusa purple cluster and S. Shyamli (used as a male parent) with a positive significant general combining ability effect, may give significant results in heterosis breeding for increasing fruit yield through various yield-attributing characters. General combining ability with a significant positive effect for these characters was also reported by many researchers in brinjal [41–45].

For making selection more effective, specific combining ability and general combining ability effects with a combination of the per se performance of parents and hybrids should be used, and specific combining ability estimates may be more favorable if one parent having high general combining ability will be considered [46]. The three best parents and hybrids based on general combining ability effects and specific combining ability effects, respectively, and their per se performance for all the quantitative traits are given in Table 4. The parent RKML-26, Pusa purple cluster, and RKML-34 exhibited a significant positive general combining ability effect for the trait fruit length, fruit per plant, marketable fruit per plant, yield per plant, marketable yield per plant, and total yield. Parent RKML-26 and Pusa purple cluster also exhibited well per se performance for fruit per plant and marketable fruit per plant; whereas, RKML-26 and RKML-34 exhibited well per se performance for yield per plant, marketable yield per plant, and total yield. Parent RKML-26 also showed a negative significant general combining ability effect and took minimum time for flowering and fruit initiation. Therefore, these parents were an essential source of desirable genes for enhancing fruit yield and yield attributing characters. In a prior study, the general combining ability effect on four characters in barley was determined to be statistically significant negative [47–50].

The crosses, viz., RKML-26 X PPC, RKML-2 X S. Shyamli, and RKML-11 X PPC recorded high and significant specific combining ability effects for fruit yield resulting from good *x* good, poor *x* good, and poor *x* good general combiners, respectively. The cross combination RKML-26 X PPC and RKML-11 X PPC also exhibited well per se performance for this trait. Hybrid RKML-2 x S. Shyamli exhibited well in per se performance for the trait earliness.

In a cross combination, if the specific combining ability effect is estimated to be high with high per se performance and having at least one parent with high general combining ability for a particular trait, such cross combination would produce desirable segregants in future generations. High specific combining ability effects resulting from crosses in which both parents are good general combiners can be attributed to an additive *x* additive gene effect and fixed [42]. The beneficial additive effects of the good general combiner parent and the epistatic effects of a poor general combiner parent that fulfils the desirable plant characteristic might result in a cross combination with a high specific combining ability effect, which indicates good *x* poor general combiner parents. Hybrids with high specific combining ability effects, manifested by poor *x* poor general combiners, can be attributed to dominance *x* dominance and are therefore not fixable.

Table 4 provides that the hybrids having higher significant estimates of specific combining ability had resulted from good *x* good, good *x* poor, good *x* average, average *x* poor, and poor *x* poor general combiners. In this study, the three best hybrids that showed high specific combining ability effects on fruit yield per plant had at least one good combiner involved, suggesting an additive *x* dominant gene interaction that could generate viable transgressive segregants in successive generations [29, 30, 35, 38, 51–53]. Stem rot causing pathogen is soilborne, has a broad host range, and is capable of long-term survival in the form of sclerotia. Sclerotinia rot was also recorded in West Bengal, India, between December and February in many brinjal genotypes. In Jharkhand, *Sclerotinia* stem rot disease of brinjal caused by *Sclerotinia sclerotiorum* (Lib.) de Bary has now become a serious threat. A previous study revealed that this infection causes a 26–47 percent yield loss in brinjal [54, 55].

Table 3: General combining ability effects for different characters of brinjal lines.

Parents/hybrids	LL	LW	NPB	PL	DF	DF50	FI	FL	FD	FPP	MFPP	FW	YPP	MYPP	SPF	TY	SSR	DM	TP	AA
										Lines										
RKML-1	−0.36**	0.66*	0.17	−0.27*	1.05	−0.46	−0.69	2.3**	2.44**	−2.97*	−3.73**	27.09**	137.42	23.33	−130.02*	0.27	−3.08	−1.41**	−10.07**	−2.28
RKML-2	−0.45**	−0.06	−0.05	−0.17	−9.62**	−9.29**	−8.27**	−0.62	−3.17**	−2.32	−2.46*	−10**	−324.76**	−300.39**	310.39**	−7.97**	6.5**	−2.47**	−5.73**	−0.58
RKML-3	−0.93**	−0.91**	−0.76**	−0.62**	−2.53**	−4.04**	−4.19**	−0.83	1.67**	−7.02**	−5.59**	−12.15**	−751.37**	−606.10**	135.14*	−17.80**	−2.25	−1.16**	7.73**	−0.82
RKML-4	−0.33**	1.24**	1.54**	0.82**	−3.37**	−0.54	0.64	−1.47**	−0.62	−4.02**	−3.91**	23.7**	−106.28	−141.65	−573.78**	−1.57	0.25	0.85**	−12.22**	−0.00
RKML-5	0.02	−0.32	−0.35	−0.37**	5.97**	7.04**	4.39**	−2.01**	0.24	−0.14	−0.36	−2.43	−38.15	−53.02	603.64**	0.9	1.08	1.39**	−2.71**	−1.21
RKML-6	−1.69**	−0.85**	−0.72**	−0.44**	−5.03**	−5.38**	−0.77	−2.57**	−2.6**	−1.9	−0.83	−16.77**	−570.76**	−426.09**	514.39	−14.35**	11.08**	0.53	13.58**	−0.94
RKML-7	−0.81**	−0.19	−0.06	0.12	12.63**	11.88**	7.72**	1.12*	−3.05**	−0.25	−1.49	−1.94	21.95	−95.16	166.56**	0.66	−3.08	1.09**	−15.92**	1.32
RKML-11	−0.19*	1.27**	0.38	0.71**	9.97**	9.79**	9.23**	3.22**	1.78**	0.16	0.19	−2	149.97	134.80	−996.53**	5.06	1.5	1.25**	6.19**	1.16
RKML-26	1.67**	−0.77**	0.09	−0.03	−6.53**	−5.79**	−5.28**	0.06	2.30**	13.65**	13.53**	−15.09**	691.77**	718.69**	169.56**	14.99**	−6.42**	0.86**	18.18**	1.93
RKML-34	3.07**	−0.06	−0.24	0.26*	−2.53**	−3.21**	−2.78*	0.79	1.51*	4.83**	4.66**	9.57**	790.20**	745.57**	−199.36**	19.82**	−5.58**	−0.93**	0.97**	1.40
SE	0.09	0.27	0.19	0.12	0.93	0.93	1.10	0.46	0.58	1.28	1.20	3.57	81.78	71.63	63.60	2.56	2.02	0.31	0.12	0.11
										Testers										
PPC	0.75**	0.39*	0.33**	0.10	2.38**	1.77**	1.66*	−0.41	−2.94**	8.31**	6.63**	−26.25**	214.07**	148.72**	76.57	5.19**	−0.75	−1.06**	−4.3**	−0.64
PPL	−0.5**	−0.2	−0.13	0.05	−0.98	−0.09	0.69	1.7**	−2.33**	1.37	1.26	−22.41**	−234.71**	−211.47**	−476.02**	−5.39**	6.25**	−1.17**	−1.29**	−0.57
S. Pratibha	−0.2**	0.23	0.14	0.19*	1.25*	0.88	1.26	0.78**	0.3	−2.32**	−2.28**	6.79**	−45.56	−75.86	488.08**	−0.91	1.75	0.54**	−3.71**	0.22
S. Shyamli	−.03	−0.42*	−0.33**	−0.35**	−2.65**	−2.56**	−3.61**	−2.07**	4.97**	−7.36**	−5.61**	41.87**	66.20	138.62**	−88.63*	1.11	−7.25**	1.69**	9.29**	0.99
SE	0.06	0.17	0.12	0.07	0.58	0.59	0.7	0.3	0.37	0.81	0.76	2.26	51.72	45.30	40.22	1.62	1.28	0.19	0.08	0.07

*, **Significant at 5% and 1% levels, respectively.

Table 4: Top three best performing parents (per se and GCA) and hybrids (per se and SCA) for various characters in brinjal.

Characters	Parental performance		Superior hybrids			
	Per se	GCA	Per se	GCA effect	SCA	GCA effect
Days to flowering	RKML-26 (53.00)	RKML-2 (−9.62)	RKML-2 X PPL (52.00)	PxP	RKML-7 X S. Pratibha (−6.83)	PxA
	RKML-34 (57.00)	RKML-26 (−6.53)	RKML-2 X S. Shyamli (52.67)	PxG	RKML-1 X S. Pratibha (−6.25)	PxA
	RKML-6 (58.67)	RKML-6 (−5.03)	RKML-26 X S. Shyamli (54.33)	GxG	RKMl-34 X PPL (−5.43)	GxP
Days to 50% flowering	RKML-26 (59.33)	RKML-2 (−9.29)	RKML-2 X S. Shyamli (60.00)	PxG	RKML-7 X S. Pratibha (−5.38)	PxA
	RKML-34 (64.33)	RKML-26 (−5.79)	RKML-26 X S. Shyamli (62.67)	GxG	RKML-1 X S. Pratibha (−5.38)	PxA
	RKML-6 (67.67)	RKML-6 (−5.38)	RKML-2 X PPL (63.00)	PxP	RKMl-34 X PPL (−4.99)	GxP
Fruit initiation	RKML-26 (68.33)	RKML-2 (−8.27)	RKML-2 X S. Shyamli (67.33)	PxG	RKML-1 X S. Pratibha (−6.34)	PxA
	RKML-34 (70.67)	RKML-26 (−5.28)	RKML-2 X PPC (69.33)	PxG	RKML-5 X PPL (−5.86)	PxP
	RKML-6 (73.33)	RKML-3 (−4.19)	RKML-2 X PPL (70.00)	PxP	RKML-2 X PPC (−5.16)	PxG
Leaf length (cm)	RKML-26 (6.53)	RKML-34 (3.07)	RKML-26 X PPC (11.2)	GxG	RKML-11 X PPC (2.43)	PxG
	PPC (6.53)	RKML-26 (1.67)	RKML-34 X PPL (10.33)	GxP	RKML-5 X S. Pratibha (2.04)	PxA
	RKML-34 (6.27)	PPC (0.75)	RKML-11 X PPC (9.93)	PxG	RKML-2 X S. Shyamli (2.00)	PxG
Leaf width (cm)	RKML-4 (18.43)	RKML-11 (1.27)	RKML-4 X PPC (18.99)	AxG	RKML-4 X PPL (1.16)	AxP
	PPC (18.12)	RKML-4 (1.24)	RKML-4 X PPL (18.72)	AxP	RKML-3 X S. Shyamli (1.11)	PxG
	RKML-7 (17.12)	RKML-1 (0.66)	RKML-11 X S. Shyamli (18.46)	PxG	RKML-11 X S. Shyamli (1.09)	PxG
No. of primary branches	RKML-7 (11.92)	RKML-4 (1.54)	RKML-4 X PPL (13.59)	AxP	RKML-4 X PPL (1.71)	AxP
	RKML-4 (11.62)	PPC (0.33)	RKML-4 X PPC (12.17)	AxG	RKML-26 X S. Pratibha (1.23)	GxA
	PPC (10.91)	—	RKML-26 X S. Pratibha (11.94)	GxA	RKML-3 X PPC (0.97)	PxG
Petiole length (cm)	PPC (6.53)	RKML-4 (0.82)	RKML-4 X PPC (6.03)	AxG	RKML-6 X S.Shyamli (0.61)	PxG
	RKML-7 (6.34)	RKML-11 (0.71)	RKML-4 X PPL (5.87)	AxG	—	
	S. Pratibha (5.94)	RKML-34 (0.26)	RKML-4 X S. Pratibha (5.85)	AxA	—	
Fruit length (cm)	RKML-26 (8.51)	RKML-6 (−2.57)	RKML-6 X S. Shyamli (11.74)	PxG	RKML-2 X PPC (−2.41)	PxG
	RKML-6 (9.77)	RKML-5 (−2.01)	RKML-5 X S. Shyamli (12.1)	PxG	RKML-3 X S. Pratibha (−2.02)	PxA
	S. Shyamli (10.81)	RKML-4 (−1.47)	RKML-2 X PPC (12.93)	PxG	RKML-34 X PPL (−2.00)	GxP
Fruit diameter (cm)	RKML-11 (26.37)	S. Shyamli (4.97)	RKML-3 X S. Shyamli (31.78)	PxG	RKML-3 X S. Shyamli (6.32)	PxG
	S. Shyamli (23.55)	RKML-1 (2.44)	RKML-34 X S. Shyamli (28.98)	GxG	RKML-1 X PPL (4.13)	PxP
	RKML-4 (22.97)	RKMl-26 (2.30)	RKML-11 X S. Shyamli (28.2)	PxG	RKML-4 X PPL (3.93)	AxP
No. of fruit per plant	PPC (33.4)	RKML-26 (13.65)	RKML-26 X PPC (47.67)	GxG	RKML-26 X S. Pratibha (5.79)	GxA
	RKML-26 (30.93)	PPC (8.31)	RKML-26 X S. Pratibha (38.8)	GxA	—	
	RKML-6 (25.13)	RKML-34 (4.83)	RKML-26 X PPL (36.2)	GxP	—	
No. of marketable fruit per plant	RKML-26 (29.33)	RKML-26 (13.53)	RKML-26 X PPC (43.24)	GxG	—	
	PPC (25.83)	PPC (6.63)	RKML-26 X S. Pratibha (34.35)	GxA	—	
	RKML-6 (23.53)	RKML-34 (4.66)	RKML-26 X PPL (33.36)	GxP	—	

Table 4: Continued.

Characters	Parental performance		Superior hybrids			
	Per se	GCA	Per se	GCA effect	SCA	GCA effect
Fruit weight (g)	S. Shyamli (224.38)	S. Shyamli (41.87)	RKML-1 X S. Shyamli (201.42)	PxG	RKML-1 X S. Shyamli (36.69)	PxG
	RKML-34 (180.82)	RKML-1 (27.09)	RKMl-4 X S. Shyamli (163.99)	AxG	RKML-26 X PPC (21.11)	GxG
	RKML-4 (177.14)	RKML-4 (23.7)	RKML-6 X S. Shyamli (142.56)	PxG	RKML-11 X PPC (20.77)	PxG
Yield per plant (g)	RKML-11 (2699.13)	RKML-34 (790.20)	RKML-26 X PPC (3464.13)	GxG	RKML-26 X PPC (760.65)	GxG
	RKML-26 (2681.73)	RKML-26 (691.77)	RKML-11 X PPC (2794.4)	PxG	RKML-2 X S. Shyamli (714.38)	PxG
	RKML-34 (2474.4)	PPC (214.07)	RKML-26 X S. Pratibha (2777.4)	GxA	RKML-11 X PPC (632.72)	PxG
Marketable yield per plant (g)	RKML-26 (2540.11)	RKML-34 (745.57)	RKML-26 X PPC (3135.42)	GxG	RKML-26 X PPC (727.06)	GxG
	RKML-11 (2307.33)	RKML-26 (718.69)	RKML-26 X S. Pratibha (2429.99)	GxA	RKML-2 X S. Shyamli (585.93)	PxG
	RKMl-34 (2268.87)	PPC (148.72)	RKML-34 X S. Shyamli (2422.42)	GxG	RKML-11 X PPC (493.03)	PxG
Total yield (ton/ha)	RKML-26 (50.66)	RKML-34 (19.82)	RKML-26 X PPC (75.29)	GxG	RKML-2 X S. Shyamli (18.20)	PxG
	RKML-11 (49.42)	RKML-26 (14.99)	RKML-11 X PPC (72.09)	PxG	RKML-11 X PPC (16.63)	PxG
	RKMl-34 (47.69)	PPC (5.19)	RKML-34 X PPC (69.38)	GxG	RKML-4 X S. Shyamli (13.10)	AxG
No. of seed per fruit	RKML-5 (2142.33)	RKML-5 (603.64)	RKML-6 X S. Pratibha (3304.33)	PxA	RKML-6 X S. Pratibha (926.34)	PxA
	RKML-3 (1948.00)	S. Pratibha (488.08)	RKML-3 X S. Pratibha (2312.33)	PxA	RKML-2 X PPL (428.11)	PxP
	RKML-1 (1821.00)	RKML-2 (310.39)	RKML-26 X S. Pratibha (2228)	GxA	RKML-7 X S. Shyamli (413.54)	PxG
Sclerotia stem rot incidence (%)	S. Pratibha (5.00)	S. Shyamli (−7.25)	RKML-26 X S. Shyamli (1.67)	GxG	RKML-2 X S. Pratibha (−12.17)	PxA
	S. Shyamli (6.67)	RKML-26 (−6.42)	RKML-34 X S. Shyamli (1.67)	GxG	RKML-3 X PPL (−9.58)	PxP
	PPC (6.67)	RKML-34 (−5.58)	RKML-1 X S. Shyamli (5)	PxG	—	
Dry matter percentage	RKML-7 (14.82)	S. Shyamli (1.69)	RKML-6 X S. Shyamli (11.81)	PxG	RKML-6 X S. Shyamli (2.47)	PxG
	RKML-11 (11.37)	RKML-5 (1.39)	RKML-7 X S. Shyamli (11.08)	PxG	RKML-7 X S. Pratibha (2.05)	PxA
	RKML-4 (10.39)	RKML-11 (1.25)	RKMl-4 X S. Pratibha (10.25)	AxA	RKMl-4 X S. Pratibha (1.74)	AxA
Total phenol (mg/100 g)	PPC (82.17)	RKML-7 (−15.92)	RKML-7 X S. Pratibha (74.16)	PxA	RKML-34 X PPL (−20.46)	GxP
	RKML-4 (83.92)	RKML-4 (−12.22)	RKML-2 X PPC (81.07)	PxG	RKML-5 X PPC (−13.91)	PxG
	S. Pratibha (84.18)	RKML-1 (−10.07)	RKML-5 X PPC (81.38)	PxG	RKML-2 X PPC (−11.19)	PxG
Ascorbic acid (mg/100 g)	RKML-26 (12.13)	—	RKML-7 X S. Pratibha (15.38)	PxA	RKML-7 X S. Pratibha (1.98)	PxA
	RKML-34 (11.13)	—	RKML-26 X S. Shyamli (14.93)	GxG	RKML-6 X PPL (1.29)	PxP
	S. Shyamli (10.96)	—	RKML-34 X S. Shyamli (14.24)	GxG	RKMl-4 X S. Pratibha (0.8)	AxA

3.1. Analysis. The present study of gene action and combining ability in brinjal revealed that although both general and specific combining ability effects are significant, the majority of nonadditive genetic variance suggested the existence of heterozygosity in the population. As this kind of genetic variation cannot be fixed, heterosis breeding is an effective approach of crop improvement. Fruit diameter, fruit per plant, marketable fruit per plant, yield per plant, marketable yield per plant, and total yield should all be considered when choosing high-yielding brinjal genotypes, either concurrently or separately. The lines RKML-26, RKML-34, and tester Pusa purple cluster were regarded as the most promising parents owing to their high potential as general combiner for majority of the yield-related traits. In order of merit for yield and yield-contributing traits, the crosses with substantial and desirable specific combining ability effects were RKML-26 X PPC, RKML-11 X PPC, and RKML-2 X Swarna Shyamli. Additionally, the cross combinations RKML-26 X PPC and RKML-11 X PPC performed well for this trait. Additionally, the hybrid RKML-2 X S. Shyamli performed well in terms of per se performance for the characteristic earliness. These crosses may be considered for commercialization if they result in a quantum leap in brinjal fruit production.

4. Conclusions

It was found from this research that the estimations of both general combining ability (GCA) and specific combining ability (SCA) effects were substantial for the majority of the characters, showing the influence of both additive and nonadditive gene effects for these characters. However, variants due to specific combining ability were much greater than variances due to general combining ability for all traits, showing a predominance of nonadditive gene action over trait expression. Pusa purple clusters RKML-26 and RKML-34 have been proven to be effective general combiners for traits that affect yield and yield attributes. In addition, the best cross for commercial production was RKML-26 X PPC with tiny cylindrical purple fruits and RKML-2 X S. Shyamli with rectangular green fruits. Heterosis breeding may be a good option for Jharkhand's resource-poor farmers to increase brinjal yields because nonadditive gene action was prevalent for all quantitative traits studied in this study. The proposed crosses should be evaluated further to ascertain their yield potential and suitability for release in Jharkhand or comparable regions. Further research indicates that integrating traditional breeding approaches with biotechnological techniques is critical for the transmission of beneficial genes (traits) into cultivated plants. Mapping the geographic distribution of occurrences will aid future research programmes, and via genomics and marker-assisted studies, genes and pathways underlying resistance to different stressors may be found, which will support future breeding endeavours.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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Supplementary Materials

Supplementary Figure 1. Pictures of some promising F_1s after crosses. (*Supplementary Materials*)

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